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The purpose of this work is to make accurate measurements in acoustic emission (AE) and ultrasonics and to relate all measurements to national standards. The problems presently under study are: (1) the characterization of AE transducers, (2) the determination of the transfer characteristics (Green's functions) of media and structures, (3) the development of well defined sources, (4) the development of high fidelity transducers, and (5) the development of improved ultrasonic and acoustic emission techniques.

Progress in FY 87 is described. The AE transducer calibration facility has been improved to maintain it as a world-class facility. The effect of test specimen characteristics have been determined both by analysis and by experiment. The feasibility of experimentally determining mechanical Green's functions has been demonstrated. A high fidelity transducer has been developed to measure dynamic, in-plane motion; its response agrees well with theoretical predictions.

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Ultrasonic Measurements Research: Progress in 1987 (Unclassified)

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ABSTRACT

The purpose of this work is to make accurate measurements in acoustic emission (AE) and ultrasonics and to relate all measurements to national standards. The problems presently under study are: (1) the characterization of AE transducers, (2) the determination of the transfer characteristics (Green's functions) of media and structures, (3) the development of well defined sources, (4) the development of high fidelity transducers, and (5) the development of improved ultrasonic and acoustic emission techniques.

Progress in FY 87 is described. The AE transducer calibration facility has been improved to maintain it as a world-class facility. The effect of test specimen characteristics have been determined both by analysis and by experiment. The feasibility of experimentally determining mechanical Green's functions has been demonstrated. A high fidelity transducer has been developed to measure dynamic, in-plane motion; its response agrees well with theoretical predictions.

CALIBRATION AND RELATED ACTIVITIES

The AE transducer calibration facility continues to be an indispensible tool for the development of special transducers as well as for analyzing the performance parameters of AE transducers. For this reason, considerable effort has been expended to upgrade the system.

The transient recorders that were originally used in the calibration system were nominal eight bit devices, which have an inherent accuracy limitation of about 1 % and could be expected to introduce quantization noise of a significant amount into the calibration signal. Further problems existed because at high slew rates (typical of the calibration signals) the original recorder's performance degraded to that of a four bit recorder. These transient recorders have been replaced by devices having nominal ten bit accuracy, better linearity, and much superior slewing performance.

Originally the calibration data analysis and storage were carried out on a mainframe computer at another location. This mainframe computer became obsolete and, for the purposes of the AE calibration, has been replaced by an IBM compatible computer, dedicated to the purpose. The new computer is advantageous because it is more convenient and the data are now readily transferable to other IBM compatible computers.

Replacement of the transient recorders and computer necessitated complete rewriting of the software associated with the calibration. The rewriting has now been accomplished, and the calibration process has been speeded up by this.

Further improvements involving replacement of the original unity-gain front-end amplifier/guard ring driver by a low noise charge amplifier are being considered. The charge amplifier has been obtained, and a second stage quiet voltage amplifier to follow the charge amplifier has been designed and built.

The prototype secondary calibration scheme which we are constructing involves the use of an NBS conical transducer as the source and another NBS conical transducer as the transfer standard. The process is viewed as being a comparison calibration. We are attempting to design the system to avoid the use of any very expensive or esoteric equipment. Hence, an inexpensive steel plate serves as the transfer medium. By using a tone-burst source and some simple gating circuitry, it is hoped to obviate using expensive transient recorders. Part of the circuitry has now been constructed, and the steel plate has been tested. Results of one such test of the steel plate are shown in Fig. 1.

TRANSDUCER LOADING EFFECT

When a transducer is attached to a structure, it becomes part of the structure. Motion of the structure in the vicinity of the transducer is modified by the transducer's presence. In calibrating a transducer, we consider the acoustical input signal to the transducer to be the motion of the surface of the structure that would have occurred if the transducer had not been present. The actual motion of the face of the transducer depends upon the interaction of the mechanical impedance of the structure with that of the transducer. The conditions of the calibration are such that the acoustical signal travels through the calibration block as in a semi-infinite medium. A calibration performed using a given structure will be valid on another structure only if the mechanical impedances of the structures as seen by the transducer are the same.

For a structure that is large enough to act like a semi-infinite medium, the mechanical impedance seen by the transducer depends on the elastic properties and density of the structure material. We have attempted to answer the question of how much the properties of the material affect the calibration results. In other words, for example, if a transducer is calibrated on a steel block, how badly in error would the calibration be if the transducer were used on a glass block?

To determine how serious this effect is, transducers were calibrated on our steel block and also subjected to surface-pulse waveforms in aluminum, glass, and methyl methacrylate plastic. The surface-pulse waveforms were generated by a pencil-break apparatus having provision for measuring the force. For each material, the surface pulse waveform was calculated at the transducer location. This calculated waveform convolved with the waveform measured for a typical pencil break event was considered to be the input to the transducer under test in each case. These tests were performed on two transducers: a commercial AE/UT unit and an NBS conical transducer. The results are shown in Figs 2 and 3. Analysis of the NBS conical transducer has been carried out by M. Greenspan [1], and the theoretical results for a transducer of this type on the same media are shown in Fig 4.

The experimental results are very approximate because the sizes of the blocks were not as large as would be desirable, and because no capacitance transducer was used as a check on the calculated waveforms. However, it is clear that the effect of loading is significant for glass and aluminum, and more than an order of magnitude for the plastic (all relative to steel). A summary of the results is given in Table I.

Table I. Reduction of transducer sensitivity owing to the material to which it is coupled. Values for the transducers are rms sensitivities for the range 0.1 MHz to 1 MHz relative to the value obtained on steel. Values of ρc and E are relative to those for steel.

	ALUMINUM	GLASS	PMMA
AE/UT transducer	0.379	0.425	0.015
NBS conical (experiment)	0.595	0.447	0.039
NBS conical (theory)	0.580	0.523	0.068
ρc	0.370	0.304	0.069
E	0.331	0.308	0.028

It appears that, for work on media having relatively low elastic moduli, it would be desirable to have transducers with relatively higher internal compliance than those now available. It would also be desirable to have a calibration system designed around a block of a compliant medium, such as PMMA.

TRANSDUCER DEVELOPMENT

The development of transducers for accurate measurement of both in-plane and out-of-plane displacement on high modulus solids has progressed well [2,3,4,5]. The theory will be useful in the design of transducers similar to the NBS conical transducers, but optimized for other applications. For example, transducers might be optimized for better high frequency response or for use on materials having low acoustic impedance (plastic).

The transducers have become useful tools for the purposes of secondary calibration, determination of the characteristics of sources, or as sources themselves. The conical transducer has also been used as the basis for development of a new impact/echo technique for detecting defects in lossy materials. Feasibility was demonstrated for concrete as part of another program at NBS[6].

One model of a transducer for detecting in-plane displacement has been completed and demonstrated. Its output has been compared with theoretically predicted waveforms (Fig. 5). The agreement is satisfying.

ADDITIONAL INFORMATION

Additional information is detailed in references 7 through 9.

SUMMARY

The AE calibration facility has been improved by the replacement of the two transient recorders by new ones having superior performance. The facility also now has a dedicated IBM compatible computer, and faster calibration processing programs.

A study was made of one aspect of transducer performance: the interactive effect between the transducer and the medium on which it is placed. The study shows that the sensitivity of the the transducer, as defined by the AE calibration, is altered significantly by the elastic properties of the medium. In some cases the effect is more than an order of magnitude.

The design of basic in-plane and out-of-plane high fidelity displacement transducers has been satisfactorily completed. The basic theory for the out-of-plane transducer is also complete. Further extensions of the design principles are contemplated.

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[8] N. N. Hsu, "Dynamic Green's Functions of an Infinite Plate - A Computer Program", NBS Internal Report, NBSIR 85-3234, Aug. 1985.

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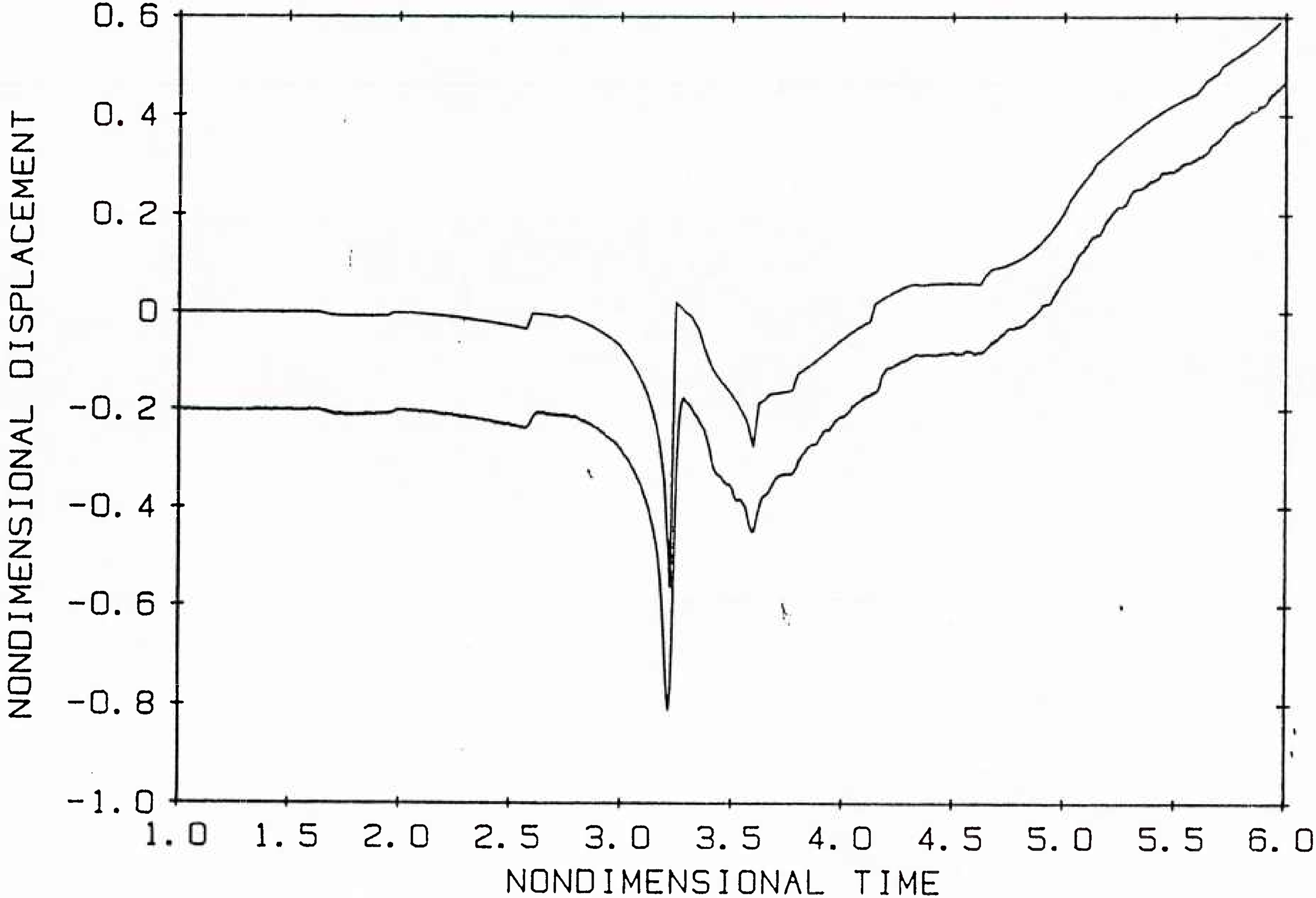
Fig. 1 Comparison of experimental waveform (lower trace) and calculated waveform for a steel plate. Conditions: source, capillary break; receiver, NBS conical transducer; plate thickness, 33 mm; source and receiver on same side, separated by 3 plate thicknesses. Calculations are performed using the program of reference 8.

Fig. 2 Approximate calibration of an AE/UT transducer done on blocks of four different materials. A pencil break was the source for all except the steel block calibration. The results were compensated for the pencil-break waveform.

Fig. 3 Approximate calibration of an NBS conical transducer. Conditions are the same as in Fig. 2.

Fig. 4 Calculated sensitivity of the NBS conical transducer of Fig. 3 on four different materials. Calculations are based on the theory of reference 1.

Fig. 5 Comparison of measured tangential displacement (lower trace) and theoretical waveform for a large steel block.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NONDIMENSIONAL DISPLACEMENT
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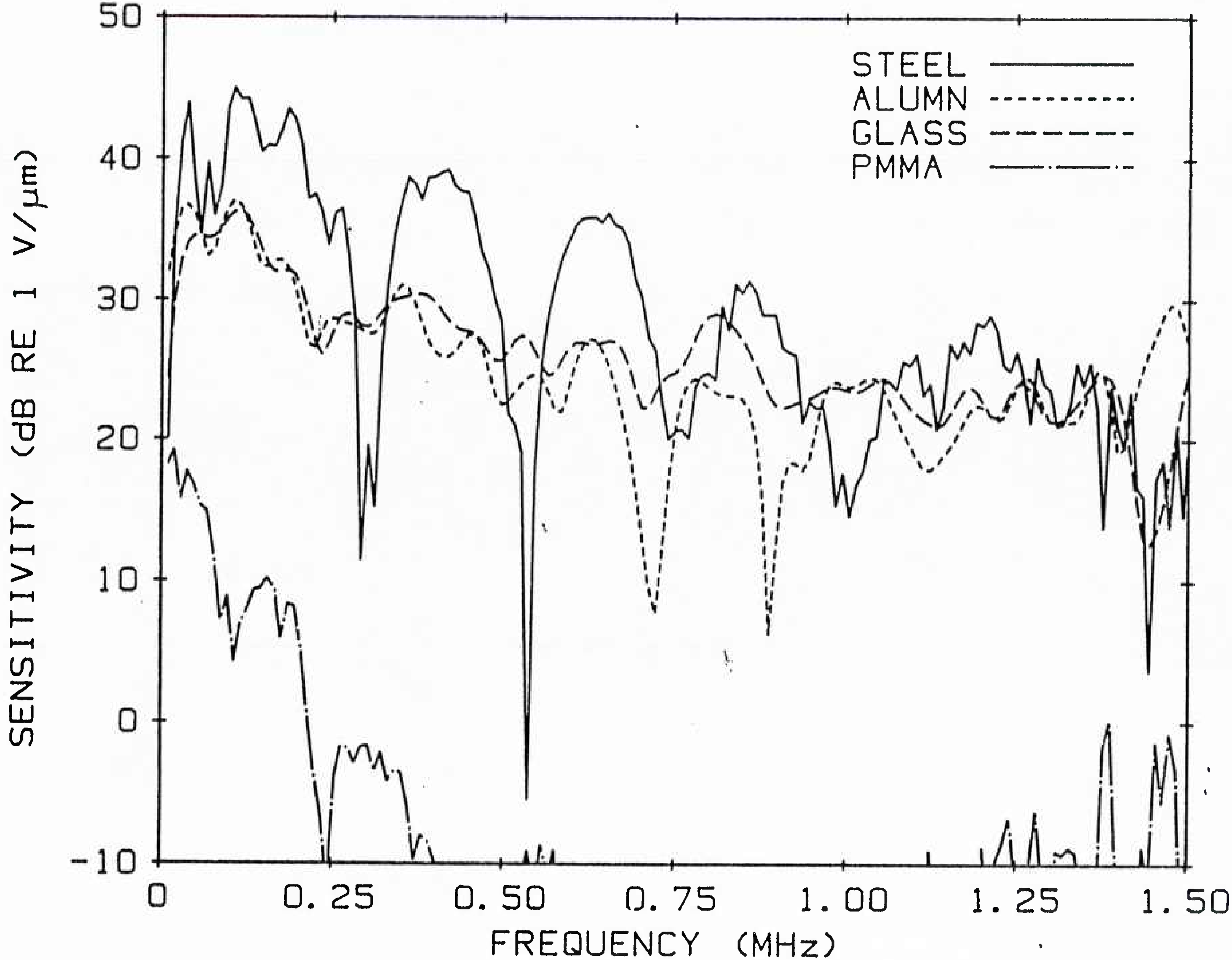
6.0
NONDIMENSIONAL TIME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ALUMN
GLASS
PMMA
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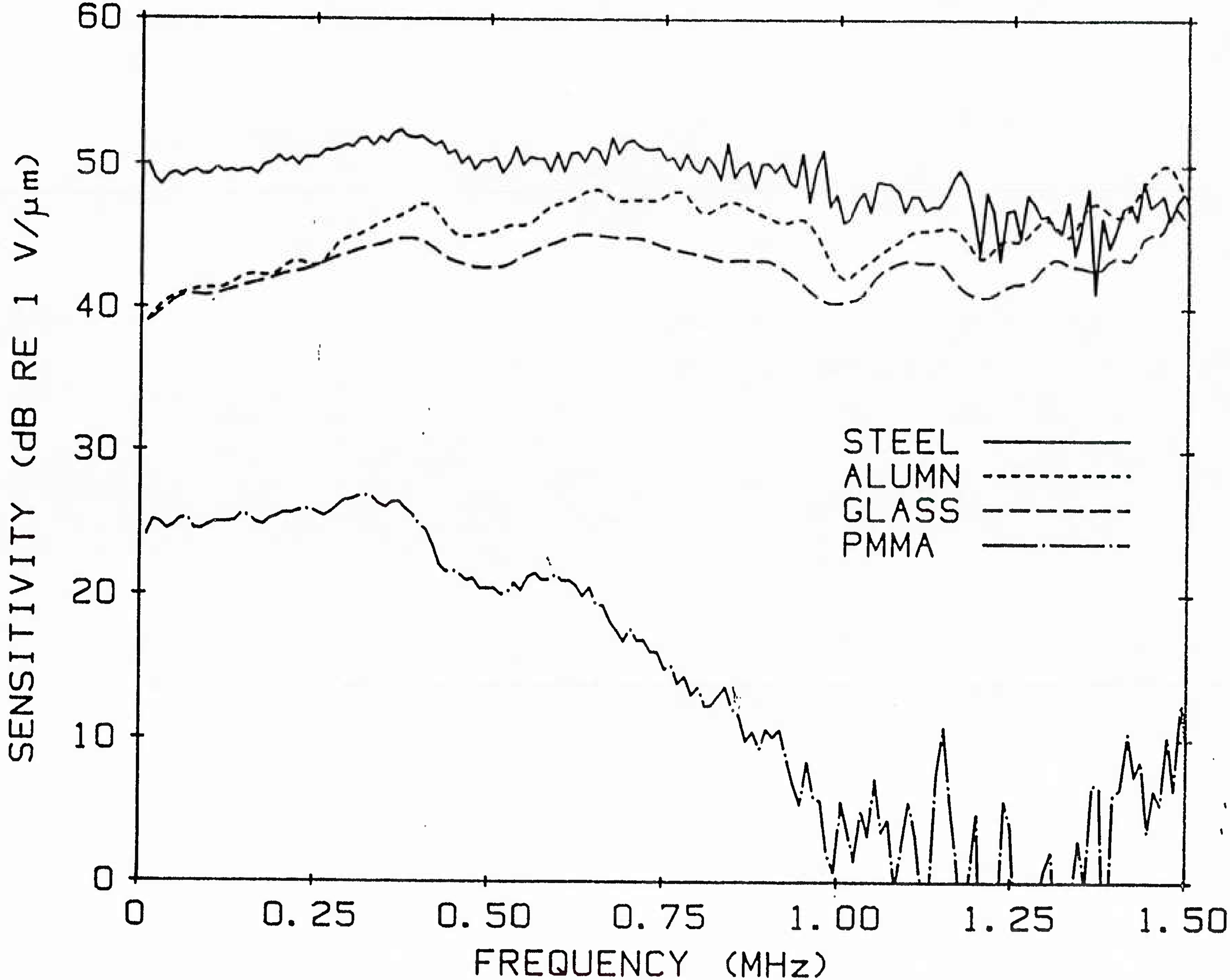
1.50
FREQUENCY (MHz)



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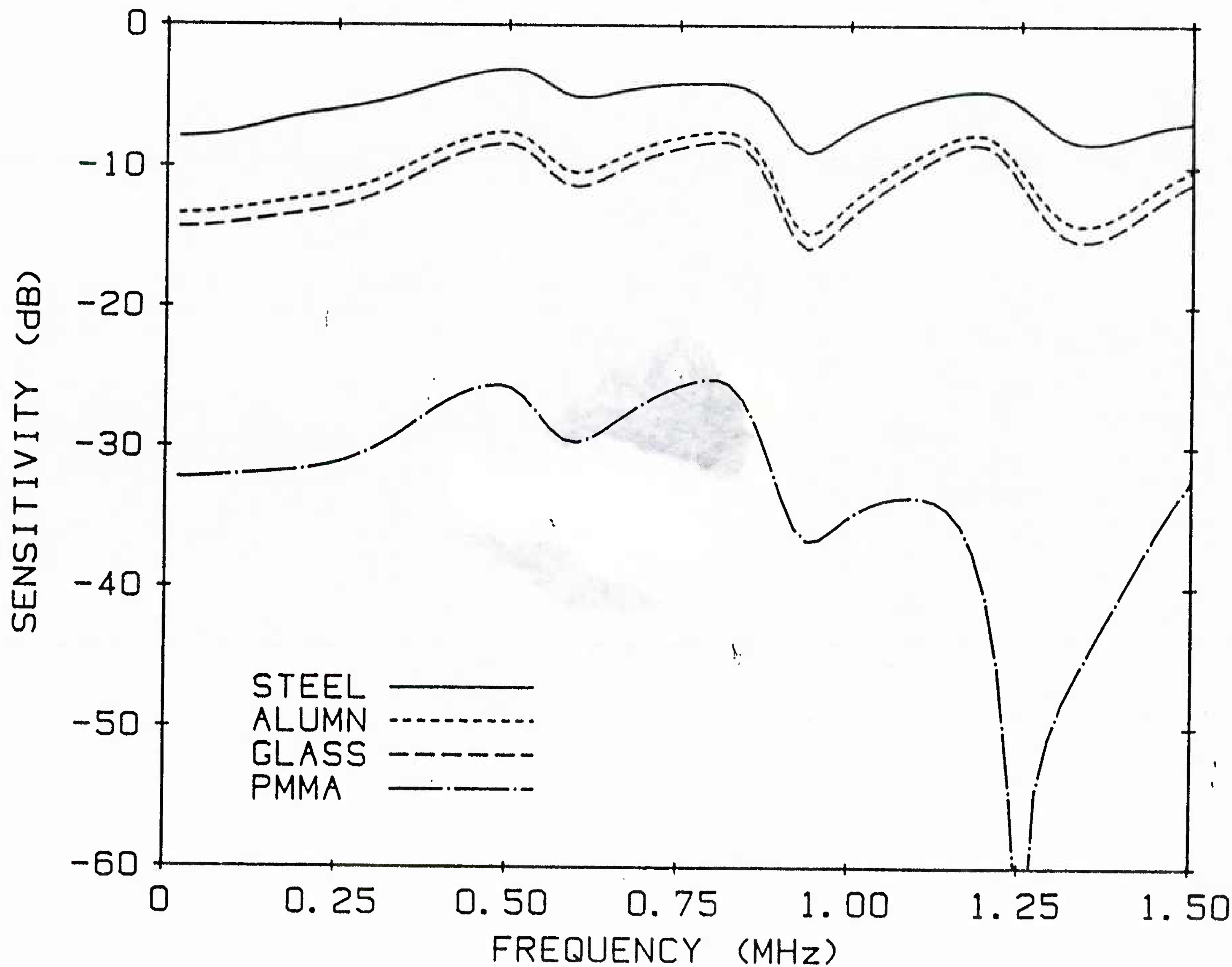
ALUMN
GLASS
PMMA



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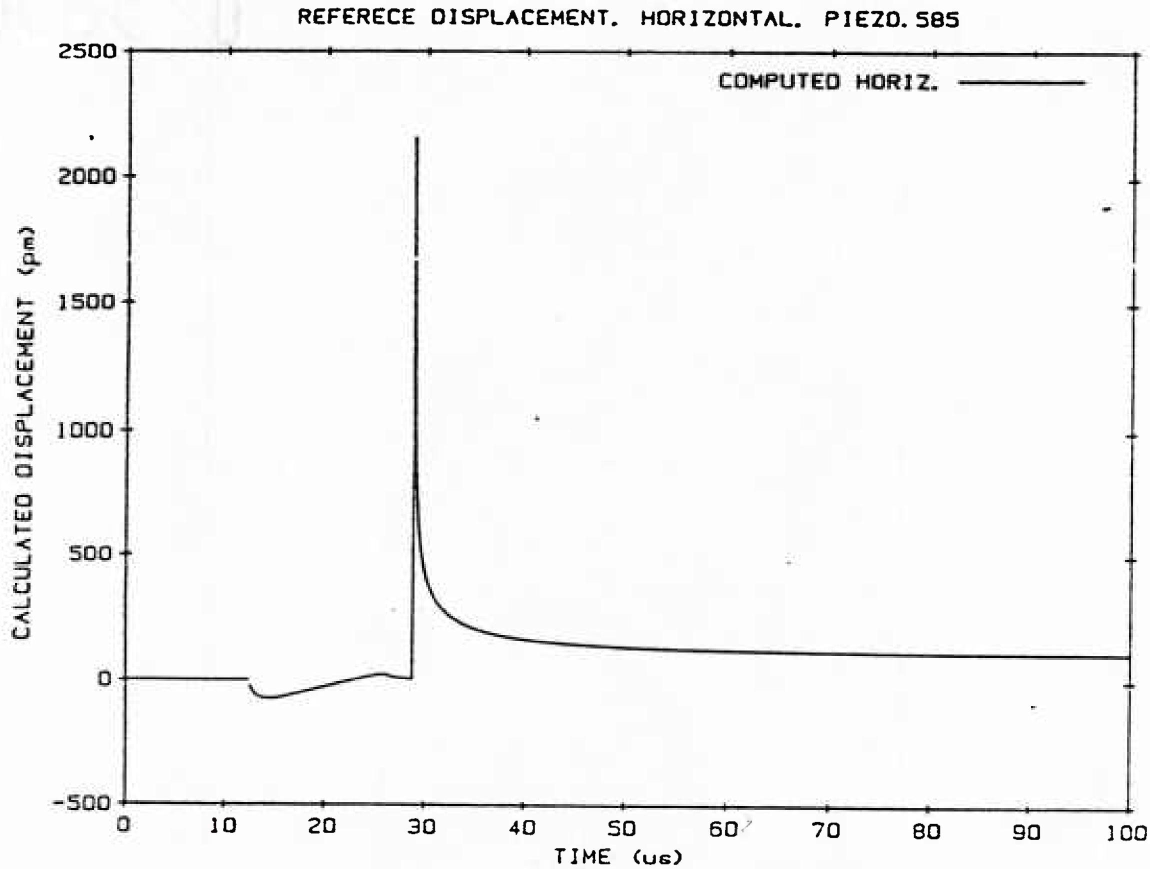
STEEL
ALUMN
GLASS
PMMA

4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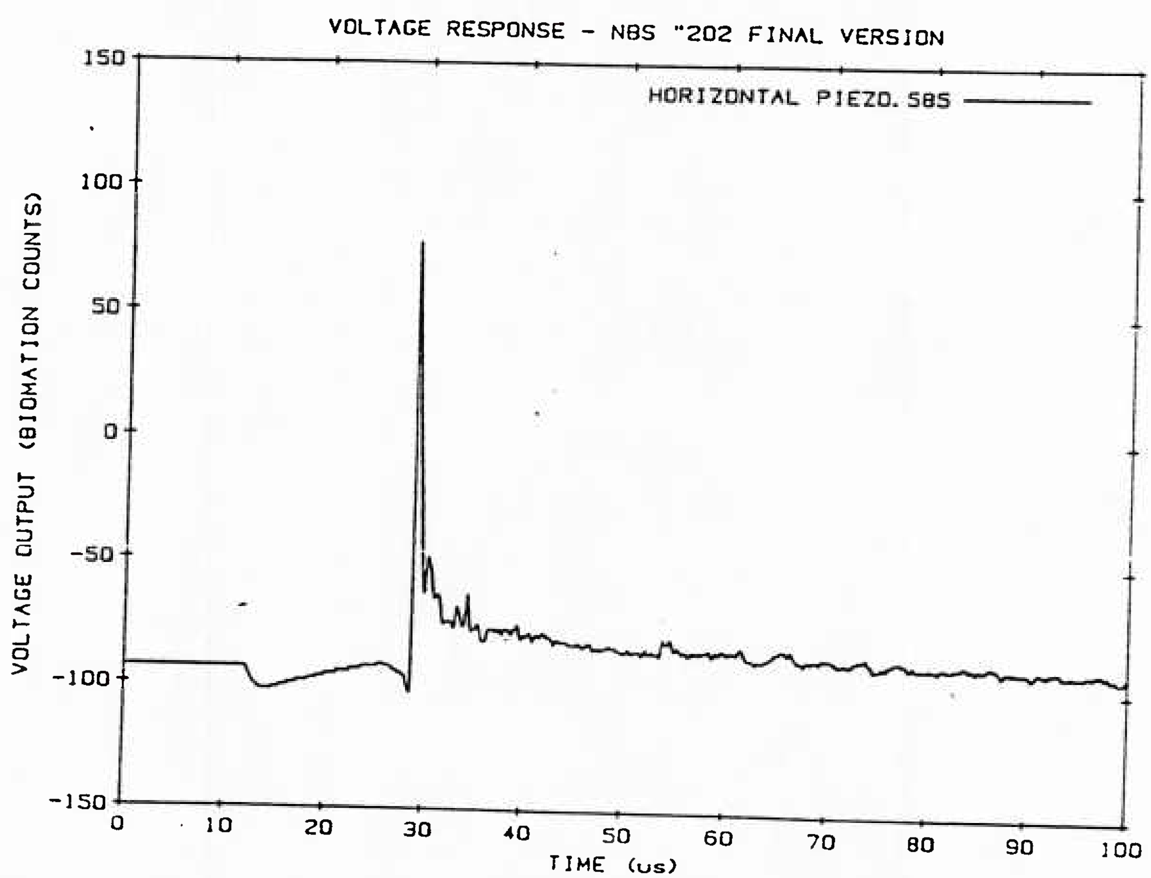
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TIME (us)